U.G. 4th Semester Examination - 2020

PHYSICS

[PROGRAMME]

Course Code : PHYG-CC-T-4(A),(B),(C)&(D)

SET-1

Full Marks : 40 Time : $2\frac{1}{2}$ Hours

The figures in the right-hand margin indicate marks.

Candidates are required to give their answers in their own words as far as practicable.

Answer all the questions from selected Option.

OPTION-A

PHYG-CC-T-4A

(Quantum Mechanics)

1. Answer any **five** questions : 2×5=10

   a) Write down the time dependent Scrödinger equation.

   b) Show that Scrödinger equation is a normal consequence of conservation of energy principle.

   c) What are the conditions that a function can be the wave function of a quantum system?

   d) Why the quantum mechanical operators are Hermitian operator?

   e) What do you mean by expectation value?

   f) What do you mean by the degenerate states of a physical system?

   g) What is Gyromagnetic ratio?

   h) What is zero-point energy?

2. Answer any **two** questions : 5×2=10

   a) Normalize the wave function $\psi(x) = Ne^{-\frac{r}{a}}$, where r is the measured distance from nucleus and *a* is the Bohr radius. Draw the distribution of wave function with spatial separation (r). 3+2

   b) Derive the eigen value and eigen functions of the operator $\left(x + \frac{d}{dx}\right)$. Show that the eigen values form a continuous spectrum. 4+1

   c) Solve the time dependent part of wave function using a time dependent Scrödinger equation. What is stationary state? 4+1

   d) What is box normalization? Explain Anomalous Zeeman effect showing a net diagram of transition between the split energy levels with required selection rules. 2+3

3. Answer any **two** questions : 10×2=20

   a) What do you mean by wave function, quantum mechanical probability, probability current density

for a quantum system? Establish the relation between quantum mechanical probability and probability current density for above system. Write down the Scrödinger equation of a quantum Harmonic oscillator. 4+4+2

b) A free particle is moving in X-direction within a confined region $0 \le x \le L$, write the Scrödinger equation for the system. Determine the energy eigen value and eigen function of the system. Show that the energy eigen values are discrete. What will be the energy eigen values if the particle is free in three dimension? 2+3+3+2

c) What is space quantization? What is Bohr magneton? What is its value? What is J-J and L-S coupling interaction? Sketch the normal Zeeman transition of sodium D_2 line $3\,^2P_{\frac{3}{2}} \rightarrow 3\,^2S_{\frac{1}{2}}$. 2+1+1+3+3

d) Write down the expression of Scrödinger equation for Hydrogen atom in spherical polar coordinate. Using separation of variable solve the azimuthal angle (ϕ) dependent solution. What is the outcome of Stern-Gerlach experiment? Write the form of energy eigen values and ground state energy eigen function of such oscillator. 2+3+3+2

OPTION-B

PHYG-CC-T-4B

(Solid State Physics)

1. Answer any **five** questions : 2×5=10

   a) Explain the translation vector in a crystal system.

   b) What is the unit cell of a crystal system?

   c) Draw the (230) plane for a simple cubic system.

   d) What is Phonon?

   e) State the limitations of Einstein's Law of specific heat of solids.

   f) What is Ferromagnetic domain?

   g) What is Type I and Type II superconductivity?

   h) Explain how can you identify the type of semiconductor by Hall effect experiment.

2. Answer any **two** questions : 5×2=10

   a) Calculate the intercepts on three axes of a plane having Miller Indices (210). Draw the (210) plane for an orthorhombic system. 3+2

   b) Calculate the number of atoms per cell for a simple cubic crystal system. Define Moniclinic crystal system. 3+2

c) What is the origin of Paramagnetism? Calculate the average value of magnetic moment vector for a paramagnetic system subjected to external field H. 2+3

d) Explain the effective mass of an electron in presence of electric field in Brillouin Zone. What is the isotope effect in a Superconductor? 3+2

3. Answer any **two** questions : 10×2=20

a) Explain the Bloch theorem. Explain the concept of forbidden energy bands. Why Hysteresis Loss happens for a magnetic system? Write the Clausius Mossotti equation for dielectric. What is Plasma oscillation? 2+2+2+2+2

b) Write down the expression of force equation for a monatomic lattice chain along x-direction. Derive the relation between angular frequency and wave-vector for such system. Draw the dispersion curve for such system. How does the dispersion curve differ in diatomic one dimensional system? What happens in the curve if both atoms in that diatomic system have same mass? 2+3+2+2+1

c) State Dulong-Petit's Law. What is the drawback of the law? How Einstein has solved the problem explain with mathematical deductions. State the how Debye propose the solution of Einstein equation for deduction of specific heat of solids. 2+2+5+1

d) What are the differences between amorphous and crystalline materials? Explain how the Basis and Lattice generate crystal structure. Does the choice of unit cell is unique? Explain how does a quartz crystal used as piezoelectric material. What is electrostrictive effect? 2+2+2+2+2

OPTION-C

PHYG-CC-T-4C

(Electromagnetic Theory)

1. Answer any **five** questions : 2×5=10

   a) What do you mean by displacement current?

   b) State the Poynting theorem.

   c) Using the Maxwell's equation derive the expression of wave equation in a dielectric medium.

   d) What is negative and positive crystal?

   e) What is retarded plate?

   f) State Biot's Law of rotatory polarization.

   g) What is relaxation time in case of electromagnetic wave propagation?

   h) What is Plasma frequency?

2. Answer any **two** questions : 5×2=10

   a) What is the origin of displacement current? State how the Ampere's Law of magnetomotive force is corrected by the concept of displacement current. 2+3

   b) What is Poynting vector? Show that average energy density in a harmonic electromagnetic field is $\langle u \rangle = \frac{1}{4}\mathrm{Re}\left[\vec{E}\vec{D}^{*} + \vec{H}\vec{B}^{*}\right]$ 2+3

   c) State the Brewster's law. Using Fresnel's formula of refraction of an electromagnetic wave, establish the Brewster's Law. Draw a neat diagram how a plane polarised light can be generated using this law. 2+2+1

   d) What is Babinet compensator? What is TE and TM mode of wave guide? 1+2+2

3. Answer any **two** questions : 10×2=20

   a) What is a wave-guide? Show that the electric and magnetic field vector satisfied the equation $\left(\nabla^2 + \frac{\omega^2}{c^2}\right)\vec{E} = 0$. Define Step and Graded indices and Numerical aperture optical fibre. Determine the numerical aperture of a step-index fibre having the core refractive index 1.50 and the cladding refractive index of 1.40. 2+3+3+2

   b) What is optic axis? Using the concept of resolution of a linear optical vibration into two circularly polarised vibration derive the expression of phase difference in terms of difference of refractive indices of left and right

circularly polarised light. Explain the basic principle of a Laurent half-shade polarimeter. A 20 cm long tube containing sugar solution gives a rotation of 11^{o} of the plane of vibration of a plane polarised light. If the specific rotation of sugar be 66^{o} $dm^{-1}.g^{-1}.cm^{-3}$, calculate the strength of the solution. 2+4+2+2

c) Write the expression of four Maxwell's equation stating the significance of each of them. Derive the wave equation from it in a conducting medium. Show that the electric field amplitude is spatially attenuated. What is skin depth? 2+3+3+2

d) Discuss the action of a Nicole prism as a polariser. Calculate the thickness of a quarter wave plate for sodium light of wavelength 5893Å. Given refractive index of ordinary and extraordinary waves are 1.5442 and 1.5533, respectively. A plane polarised electromagnetic wave is incident in the interface of a two dielectric medium having refractive index μ_1 and μ_2, find the relation between angle of incident and angle of refraction. 2+3+5

OPTION-D

PHYG-CC-T-4D

(Statistical Mechanics)

1. Answer any **five** questions : 2×5=10

   a) What is the difference between macroscopic and microscopic states?

   b) State and explain the basic postulate of equal a priory theory.

   c) What is entropy of a statistical system under thermal equilibrium?

   d) State the limitations of Wines displacement law.

   e) What is Fermi energy?

   f) Write the expression of FD distribution function.

   g) What are the properties of liquid Helium?

   h) Define Micro-canonical and Grand-canonical ensemble.

2. Answer any **two** questions : 5×2=10

   a) Show that the mean energy per degrees of freedom of a molecular assembly at absolute temperature T is KT. 5

   b) What is ideal gas? Assuming the free particle concept of an ideal gas derive the expression of equation of state of such gas. 1+4

c) Show that the value of Fermi energy is $E_F = \frac{h^2}{2m}\left(\frac{3N}{8\pi}\right)^{\frac{2}{3}}$. The molar mass of Li is 0.00694 and its density 0.53×10^3. Calculate the Fermi energy and Fermi temperature of electron. 3+2

d) Why the electron in a white dwarf star is considered as degenerate? Using First law of thermodynamics show that the product of wavelength of emitted radiation varies inversely to the absolute temperature. 2+3

3. Answer any **two** questions : 10×2=20

a) A particle of unit mass is executing simple harmonic oscillation. Explain the trajectory of the particle in phase space. Explain how μ -space is defined and what is the minimum dimension of each phase cell in that space? What is partition function? Derive the expression of partition function for a Grand-canonical system. 3+3+1+3

b) Calculate the probability that a small system be in energy state E resides in a big micro-canonical ensemble having energy E_0 under equilibrium, established by energy exchange only. Assuming the partition function (Z) of a canonical ensemble as a function of β and energy E, show that the entropy of the system becomes $S = k\left(\ln Z + \beta\langle E\rangle\right)$. T=equilibrium absolute temperature and $\beta = \frac{1}{KT}$. Express the Helmoltz free energy of a canonical system in terms of partition function and temperature. 4+3+3

c) Derive the expression of number of bosons (using grand canonical ensemble concept) present in a particular energy state E_s. What conclusion can you draw about the minimum energy of a boson from the expression? Show that for an ideal Bose gas the product of its pressure (P) and volume (V) related to mean energy (E) by $PV = \frac{3}{2}E$. Explain qualitatively the phenomena of B-E condensation. 3+1+4+2

d) Show that the amount of radiation emitted from a black body at absolute temperature T_1 surrounded by another black body at absolute temperature T_2 is $Q = \sigma\left(T_1^4 - T_2^4\right)$. σ is a constant. Using First law of thermodynamics show that the product of wavelength of emitted radiation varies inversely to the absolute temperature of the body. State the limitations of Rayleigh-Jeans Law. What is Chandrasekhar limit? 4+2+2+2

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